

Exploring the Impact of User-Centered Design on Quality Enhancement in Coffee Processing in Sri Lanka

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Abstract – *The quality of Sri Lankan coffee production depends largely on post-harvest processing methods, where small-scale farmers play a vital role. This study explores how User-Centered Design (UCD) principles can help improve the quality of coffee while reducing the physical strain faced by small-scale farmers. Field research was carried out in Maskeliya (Hatton) and Galkanda (Nuwara Eliya), involving ten farmers who practice both wet and dry processing methods. Data were collected through observations and semi-structured interviews during processing activities. The study identified recurring issues such as repetitive manual work, poor ergonomic conditions, and outdated equipment that affect both farmer well-being and coffee quality. A comparison between wet and dry processing revealed that wet processing results in better coffee quality but requires more physical effort. The paper suggests that integrating UCD principles can improve tool design, reduce manual effort, and enhance workflow efficiency, ultimately supporting higher-quality production. This research highlights the potential for participatory and ergonomic design approaches to strengthen Sri Lanka's coffee industry through improved farmer experience and sustainable processing practices.*

Keywords: *User-Centered Design; Coffee Processing; Ergonomics; Quality Enhancement; Sri Lanka; Agricultural Design Innovation*

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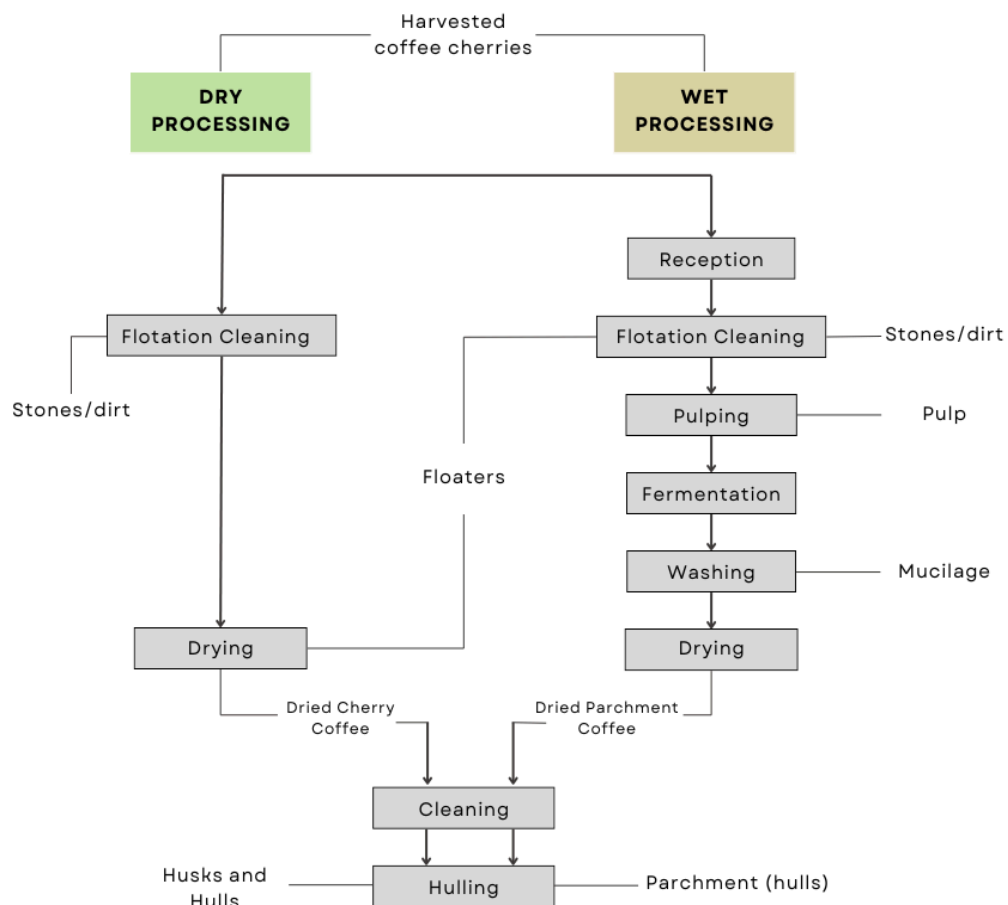
I. Introduction

Coffee consumption has seen a global increase, driving high demand for quality coffee (Coffee Market Report, December 2023). Sri Lanka, with its advantageous location within the coffee belt, is well-positioned to grow even the most demanding coffee varieties. The quality of coffee is influenced by four primary factors: geographical environment, harvesting, processing, and roasting. Among these, harvesting and processing are directly handled by farmers, making them key contributors to the quality of the final product.

Coffee processing methods—wet and dry—are important in transforming coffee cherries into green beans for roasting. Wet processing the fruit pulp is removed using water, producing coffee with a clean and quality taste, while dry processing dries the entire cherry under the sun, resulting in a more caffeine, fruitier taste but not quality as wet process. The method used affects the taste and quality of the coffee and depends on factors like climate and available resources.

Figure 1

Various coffee processing methods (Source: Author's field documentation, 2025)



Farmers are deeply involved in these processes, making decisions that affect the quality of the coffee. In Sri Lanka, both wet and dry methods are commonly used, with processing decisions being influenced by factors such as climate and location.

This study investigates how user-centered design principles can enhance coffee quality by improving ergonomic practices and reducing manual labor intensity among Sri Lankan coffee farmers.

II. Literature Review

This chapter aims to explore the role of user-centered design (UCD) in agriculture, particularly in improving product quality and efficiency. It examines how UCD addresses labor-intensive agricultural processes, specifically in tea and rice production. The review identifies gaps in existing research and highlights how UCD can optimize farming practices to improve product outcomes and worker well-being.

User-centered design focuses on meeting the needs and behaviors of users throughout the design process. UCD creates products that are accessible, usable, and effective by incorporating user feedback at each stage (IxDF, 2016). Norman (2013) emphasizes UCD's role in ensuring products are intuitive and address real user needs.

In agriculture, UCD tailors tools and systems to the needs of farmers, particularly small-scale producers. This approach reduces labor and improves productivity by ensuring products are responsive and effective (Gonzalez et al., 2024). By improving agricultural tools and processes, UCD helps farmers adapt to dynamic farming conditions (Rose et al., 2018)

UCD has shown potential in improving both crop quality and productivity by addressing real-world challenges. For example, ergonomic tools and user-friendly interfaces in tea and rice production improve efficiency and product quality by reducing labor intensity and physical strain.

Evidence from tea and rice production demonstrates that ergonomic and user-centered design approaches directly enhance worker safety and efficiency. Ergonomically designed tea-plucking tools and baskets have reduced injury risk and improved harvesting speed (Bhattacharyya & Chakrabarti, 2012), while methods such as Alternate Wetting and Drying (AWD) in rice cultivation have improved water management and reduced strain (Mote et al., 2020). These findings prove that design interventions tailored to user needs can transform agricultural productivity and sustainability.

However, while these studies show clear benefits of UCD in other crops, there is a lack of research applying UCD to coffee production, especially in Sri Lanka. Coffee processing involves complex manual tasks—such as pulping, fermenting, washing, and drying—that are physically demanding and directly affect bean quality. Yet, few studies have examined these processes from the farmers'

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perspective or explored how ergonomic design can improve both the working experience and final product quality.

This research addresses that gap by exploring how UCD principles can be applied to the coffee processing context in Sri Lanka. It aims to identify user-centered opportunities to reduce physical strain, improve efficiency, and enhance coffee quality through design-led solutions tailored to small-scale farmers.

III. Methodology

Building on the previous chapter's literature review, which highlighted the need to understand coffee processing through the farmers lived experiences, this chapter outlines the comprehensive methodology adopted for this study. The research design is qualitative in nature, utilizing ethnographic research methods with field observations and semi-structured interviews. This interpretive approach was chosen to capture real, lived experiences of small-scale farmers during coffee processing, providing contextually rich data that cannot be achieved through quantitative measures alone.

A. Participant Selection and Study Region

The study involved ten small-scale coffee farmers from Maskeliya (Hatton) and Galkanda (Nuwara Eliya) –two key coffee-producing regions in Sri Lanka. These sites were chosen for their varying terrain and climatic conditions, which influence the adoption of wet and dry processing methods. Farmers were selected through purposive sampling, focusing on those with direct hands-on experience in both processing methods.

B. Data Collection

Data collection involved field observations and semi-structured interviews conducted during the active coffee processing period. Each interview lasted approximately 15 minutes, depending on the workflow and participant availability. Field observations captured details of repetitive tasks, tool handling, working postures, and spatial arrangements within the processing sites.

A pilot study was conducted with two farmers prior to data collection, which helped refine the interview guide and observation criteria. The main study then incorporated these improvements to ensure the clarity and relevance of questions related to user experience and ergonomic factors.

C. Data Analysis and Embedding UCD Principles

The collected qualitative data were analyzed using thematic analysis, which allowed identification of patterns such as physical strain, manual workload, repetitive movements, and equipment inefficiencies. To embed User-Centered Design (UCD) principles into the analysis, each emerging theme was interpreted through a design perspective. For instance, challenges identified in posture and task repetition were analyzed through the usability and comfort lenses of UCD, while farmers' comments about tool performance were evaluated in terms of feedback and accessibility.

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Through this interpretive process, user-centered insights were derived by mapping farmers’ behaviors and feedback against UCD principles. Although formal participatory sessions were not conducted, informal feedback loops emerged naturally during field interactions, as farmers discussed how existing tools could be redesigned to better support their work. These reflections directly informed the study’s understanding of ergonomic improvement opportunities.

D. Limitations

The research was limited by its small sample size and geographic scope, covering two main regions. Additionally, time constraints during the harvest season restricted extended observation periods. Despite these limitations, the study provides valuable qualitative insights into the ergonomic and user-centered aspects of Sri Lanka’s coffee processing sector.

IV. Data Analysis and Results

This chapter presents a detailed analysis of the challenges faced by small-scale coffee farmers in Sri Lanka, focusing on the wet and dry processing methods used in coffee production. The first section addresses the research question: “How do small-scale coffee farmers engage with the labor-intensive coffee processing methods in Sri Lanka?” Through interviews and field research, the findings highlight significant labor, technological, and ergonomic challenges faced by farmers. The second section explores how User-Centered Design (UCD) principles can guide practical interventions to improve coffee quality and farmer well-being.

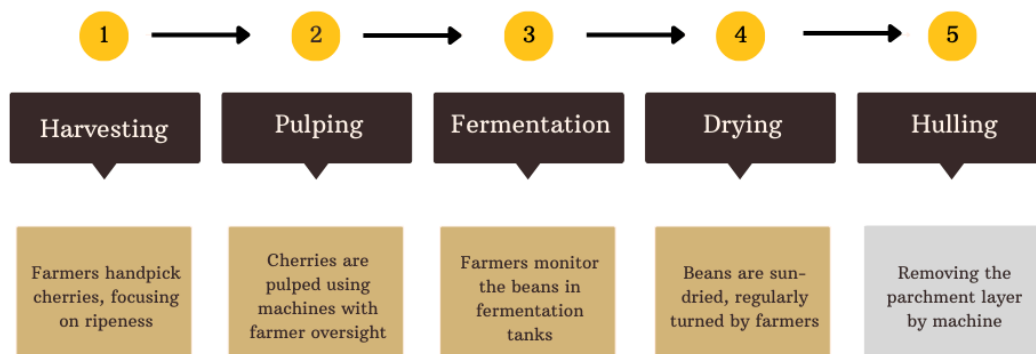
Based on the research conducted in Sri Lanka’s coffee-growing regions, two main processing methods were identified—wet and dry—each with distinct workloads, physical demands, and quality outcomes.

A. Wet Processing

Wet processing involves multiple stages such as harvesting, pulping, fermenting, and drying the coffee cherries. It is highly labor-intensive and often results in physical strain due to the repetitive nature of tasks like washing, pulping, and sorting.

Figure 3

Wet processing method: farmer interaction steps



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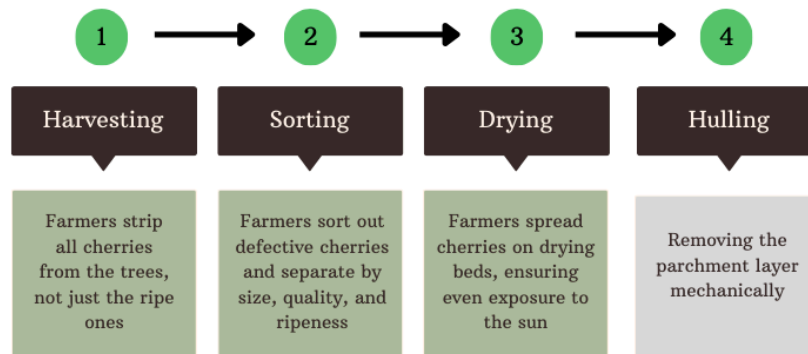
- Labor Intensity: Continuous manual labor is required for sorting, washing, and handling cherries, often leading to muscle strain and back pain.
- Technological Gaps: Despite producing higher-quality coffee, this method lacks modern machinery to reduce effort. Farmers rely on manual pulpers and wooden drying racks, increasing physical fatigue.
- Observed Instance: One farmer from Maskeliya explained, “We use our hands to wash the beans for hours; it’s tiring, but machines are too costly for us.” This reflects the strain and technological gap present in current practices.

B. Dry Processing

Dry processing is considered less labor-intensive compared to wet processing but still presents its own challenges, especially in terms of sorting and drying the coffee cherries.

Figure 4

Dry processing method: farmer interaction steps



- Physical Demand: Although it involves fewer stages, manual sorting and raking under the sun require long hours of physical work.
- Lower Quality: The lack of proper sorting tools often leads to inconsistent bean quality.
- Observed Instance: A farmer from Galkanda noted, “If rain comes suddenly, we have to run and cover everything ourselves. It’s hard work, and quality drops fast.”

C. Comparative Analysis of Wet and Dry Processing

Table 1

Comparison of Wet and Dry Processing Methods among Small-Scale Farmers in Sri Lanka

Aspect	Wet Processing	Dry Processing
1. Labor Intensity	Very high – constant washing, sorting, and pulping	Moderate – limited to drying and sorting
2. Physical Strain	Frequent bending, lifting, and repetitive movements	Moderate, mainly during raking and carrying

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3. Technology Use	Mostly manual tools and wooden drying platforms	Sun drying, minimal mechanical support
4. Quality Outcome	High flavor quality and consistency	Lower quality, risk of uneven drying
5. Main Ergonomic Issues	Back pain, shoulder strain, repetitive motion	Heat exposure, fatigue from prolonged standing

Source: Field observations and interviews, Maskeliya & Galkanda, 2025

This table highlights that wet processing, while producing superior quality, places greater ergonomic and labor pressure on farmers, reinforcing the need for user-centered ergonomic intervention.

D. User-Centered Design (UCD) in Coffee Processing

Applying UCD principles to these findings provides a framework for improvement. Farmers' feedback revealed that most challenges relate to tool usability, work posture, and repetitive physical tasks. UCD interventions—such as ergonomic pulping handles, improved washing stations, and adjustable drying racks—can significantly reduce strain.

These improvements align with UCD principles of:

- Usability: Simplifying repetitive processes and minimizing unnecessary movement.
- Accessibility: Ensuring tools are suitable for varying body sizes and abilities.
- Feedback: Incorporating farmers' input during prototype development and testing to refine designs.

By emphasizing farmer participation, UCD can transform traditional manual processing into safer, more efficient, and higher-quality production systems.

E. Challenges in Market Access and Financial Limitations

Small-scale coffee farmers face barriers to entering global markets due to limited resources. High-quality, wet-processed coffee requires more investment in infrastructure, which most cannot afford. This financial gap prevents many from upgrading to better equipment.

- Quality Standards: Wet-processed coffee earns higher market prices but needs costly equipment.
- Global Competition: Farmers using dry processing struggle to compete with large producers in countries like Brazil and Vietnam that benefit from advanced mechanization.

F. Impact of Processing on Coffee Quality

Wet processing consistently produces better-quality coffee with cleaner flavor profiles. However, its high labor demand limits sustainability for small farmers. Dry processing is easier to manage but often results in uneven quality due to limited control and outdated tools.

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Discussion

This study demonstrates that applying user-centered design principles to coffee processing can enhance both coffee quality and farmer well-being by reducing physical strain and improving the overall processing experience. The findings show that the wet method, although producing better-quality coffee, is physically demanding, while the dry method is less labor-intensive but leads to lower-quality outcomes. Understanding these differences through the farmers' perspective makes it clear that improving comfort, posture, and workflow can contribute directly to product quality.

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